Journal of Atmospheric and Solar-Terrestrial Physics 142 (2016) 72–82

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Research Paper

Observation of intensity of cosmic rays and daily magnetic shifts near meridian 70° in the South America

E.G. Cordaro [a,b], D. Gálvez [a], D. Laroze [c,*]

[a] Observatorios Radiación Cósmica y Geomagnetismo, Universidad de Chile, Casilla 487-3, Santiago, Chile
[b] Facultad de Ingeniería, Universidad Autónoma de Chile, Pedro de Valdivia 425, Santiago, Chile
[c] Instituto de Alta Investigación, Universidad de Tarapacá, Casilla 7D, Arica, Chile

ARTICLE INFO

Article history:
Received 18 June 2015
Received in revised form
17 January 2016
Accepted 18 February 2016
Available online 19 February 2016

Keywords:
Sunset enhancement
He neutron monitor
Magnetic reconnection
Cosmic rays

ABSTRACT

In analysis of experiments carried during September 2008 using secondary cosmic ray detectors located in Chacaltaya (Bolivia) and Niteroi (Brazil), Augusto et al. (2010) showed an increase in the intensity of charged particles which takes place 3 h after sunrise and lasts until 1 h after sunset, furthermore they said that during this period the solar magnetic field lines overtake the Earth's surface. These stations are located within the South Atlantic Magnetic Anomaly (SAMA), having both different magnetic rigidities. To reproduce data from the Niteroi and Chacaltaya stations, we record data during the same hours and days using our neutron monitors, muon telescopes and magnetometers within the stations Putre and Los Cerrillos. Our observation stations in Putre and Cerrillos are located at 18°11′47.8″S, 69°33′10.9″W at an altitude of 3600 m and 33°29′42.3″S, 70°42′59.81″W with 570 m height above sea level, respectively. These stations are located within the South Atlantic Anomaly (SAMA) and are separated approximately 1700 km from each other and 1700 km from the center of the anomaly. Our network is composed furthermore by two auxiliary Cosmic Ray and/or Geomagnetic stations located at different latitudes along 70°W meridian, LARC and O'Higgins stations, which are located within Antarctic territory, covering a broad part of the Southern Hemisphere.

Our magnetometer data shows that for each of the components, shifts in the magnetic field intensity for every station (even for those out of the SAMA) lasted between 3 and 4 h after sunrise and 1 and 2 h past sunset, which are the periods when the geomagnetic field is modulated by the transit of the dayside to nightside and nightside to dayside. We believe that, although the magnetometric data indicates the magnetic reconnection for the Chilean region, there is no direct influence from the SAMA other than the lower rigidity cut-off that leads to an increased count rate. Other details about the magnetic field components such as muon and neutron count rate, diurnal variation and"sunset enhancement' are reported in this work.

1. Introduction

It has been theorized by Augusto et al. (2010), that The South Atlantic Magnetic Anomaly (SAMA), now located over South America, would be responsible for a specific rise in the secondary particle production that occurs during the period between 3 h after sunrise until 1 h after sunset. This increase in the secondary particle production shows that the SAMA region promotes the precipitation of high-energy particles, with energies above the pion production threshold, which generate an air shower of particles from the Earth's atmosphere. The hard components of this shower (Muons) are able to reach sea level. This can be translated into an intense but narrowed variation of the muon and neutron count rate, as well as magnetic field intensity.

The aim of this work is to reproduce the results of the specific raise in the secondary particle production generated by the South Atlantic Magnetic Anomaly (SAMA) that occurs 3 h after sunrise until 1 h after sunset. These results have been obtained in different experiments done in Niteroi (Brazil), which is located at sea level, and Lago-Chacaltalla (Bolivia) at 5200 m.a.s.l. These two stations are separated by 2700 km and lie within SAMA region.

In order to examine the diurnal variation rate during the same period of time, we have used our cosmic ray and geo-magnetic observatories in the Chilean Network, as described in Section 2 and in full extent in Cordaro et al. (2012). The main experiments are done in the High Mountain Observatory Putre-INCAS (PUTRE), at 3598 m.a.s.l. and at Los Cerrillos Observatory (OLC) at 570 m.a.s.l. These stations are located inside of the SAMA and form an

* Corresponding author.
E-mail address: dlarozen@uta.cl (D. Laroze).

http://dx.doi.org/10.1016/j.jastp.2016.02.015
1364-6826/

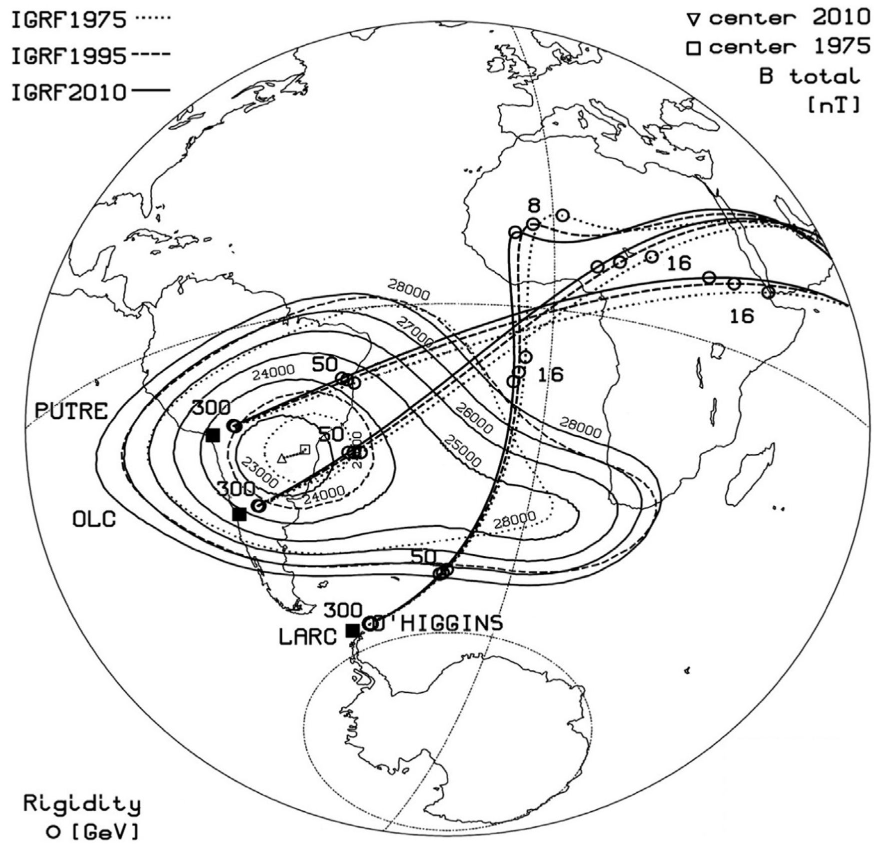

Fig. 1. Geomagnetic B total field intensity map with the variability of the South Atlantic magnetic anomaly and the particle asymptotic directions arrivals map for Putre, Los Cerrillos, LARC and O'Higgins stations (both nearly identical directions of arrivals). The SAMA center and its extension towards the Chilean coast are clearly shown. Image drawing from IGRF model and programs for asymptotic direction calculation, which means the path through a charged particle to reach its zenith point (Pomerantz, 1971).

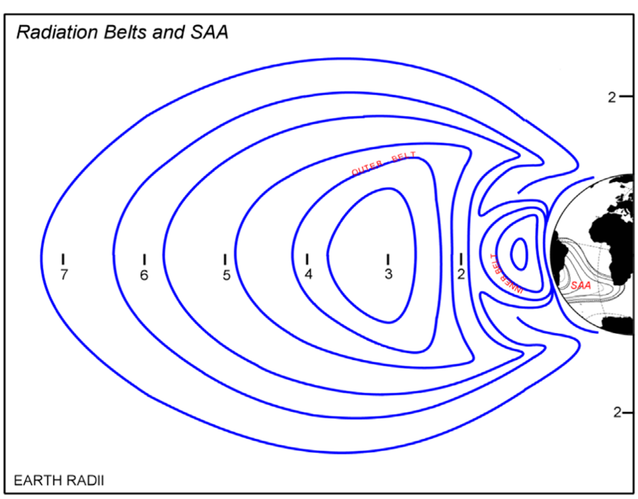

Fig. 2. South Atlantic Anomaly forming the anisotropy on the inner Van Allen belt. Image sketched from IGRF/AP8M models and NASA/ESA sources.

almost perfect equilateral triangle with the center of the anomaly at approximately 1700 km (1636 Km average), see Fig. 1. Furthermore, our two observatories have different magnetic cut-off rigidities, like the observatories in Brazil and Bolivia. The experiments were performed in September 2008 (Augusto et al., 2010).

There are some factors that should be taken into account such as: The changes in the barometric pressure that indicates how the mass of atmosphere above the instruments varies and the effects of the earth's magnetic field on the motion of the particles of cosmic rays from a height of 20 km to the ground. In the first case we have eliminated the pressure dependence of the counting rate and we have determined the primary cosmic variations at all observatories, calculating an attenuation coefficient of 0.8289 ± 0.0026%/hPa, at an average pressure level of 664 hPa, for the Neutron counter He 3 at Putre-Incas. At OLC, the BF3 neutron counter gives an attenuation factor of $0.684 \pm 0{:}014$%/hPa, at an average pressure level of 958 hPa. At the Antarctic Observatory Cosmic Rays and Geomagnetism (LARC), the calculated attenuation coefficient was $0.750 \pm 0{:}016$%/hPa at an average pressure level of 989 hPa. (Cordaro et al., 2012; Cordaro and Storini 1995, 2001). In the second case we have obtained the value of magnetic rigidity cut off and geomagnetic field (Priest and Forbes, 2000).

The South Atlantic Magnetic Anomaly (SAMA) is an area located over South America, drifting from the South Atlantic region into the Andes mountain range, where the field intensity at the Earth's surface has a weak minimum, less than 22,600 nT. This is mainly due to the additional contribution of the quadrupole component of the main field, which creates a local dip on its total magnetic field. Because of the Earth's inner Van Allen radiation belt follows the shape imposed by the magnetic field, this comes closest to the Earth's surface, a few hundred kilometers away as it is shown in Fig. 2. This leads to an increased flux of energetic particles in this region where the instruments and electronics of satellites can be severely damaged from radiation.

According to the IGRF-11/2010 data (IAGA, 2010), the magnetic field strength in the center of the SAMA region (26.5°S, 56.5°W) has an approximate value of 22,552 nT. The anomaly is considered to extend a region up to field strength of 28,000 nT, covering a wide area between the South Atlantic to the Chilean coasts and its slow variations (see Fig. 1) have not significant impact during our measurements (September 2008). Currently, close the 24.000 nT